A Process for Continuous High-Flavoring of Maple Sirup

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SUMMARY

A new heat process was developed that permits the continuous treatment of maple sirup to develop more flavor and color in the sirups. This process, utilizing temperatures well above the normal (atmospheric) boiling temperatures of the sirups, requires a very short heating time. The conditions of temperatures and of heating times are easily and quickly changed, which permits production of sirups that meet the required flavor and color specifications for different end uses.

INTRODUCTION

The flavor of maple sirup is developed during the atmospheric boiling of maple sap to concentrate it to sirup density. Low-temperature concentration of normal maple sap (contains about 2% sugar) to sirup or to complete dryness produces a product devoid of maple flavor (Willits and Porter, 1950; Willits *et al.,* 1952). Maple flavor is developed in this flavorless sirup by heating it. The effect of heating sirups under various conditions of temperatures and water content has been reported (Porter *et al.,* 1952). Also, it has been found that the usual commercial process of concentration by atmospheric boiling does not convert all flavor precursors in sap to maple flavor. Willits and Porter (1950) found that heating the average commercial standard-density sirup at temperatures above its normal atmospheric boiling point (250–255°F) produced sirups with increased flavor. The extent of flavor development was dependent on both the temperature elevation (amount of heat) and on the duration of the heating period. A public-service patent for the enhancement or high-flavoring of maple sirup by heat was issued, based on their work (Willits and Porter, 1951). While the Willits-Porter process involved heating the sugar-sirup at low water content to retard "caramel" formation, it and the process of Whitby (1936), in which the sirup was heated by autoclaving, had two objectionable features: 1) the sirups have to be processed batchwise; and 2) there is little or no flexibility in changing the heat conditions or time of heating of each individual batch.

To overcome these objections, a new, continuous process, described in this paper, has been developed. By the new process, maple sirup is passed continuously under pressure through a heat-exchanger to raise it quickly to some elevated temperature. It is held at this temperature for a period and then passed through a second heat-exchanger to lower its temperature quickly to a point below that of its atmospheric boiling point (*ca* 219°F) before it is released to atmospheric pressure through a relief valve. Also reported in this paper are the effects of the amount of heat and time of heating (hold-up time) by this continuous process on the flavor, color, pH, and sugars of maple sirup.

EXPERIMENTAL

The apparatus for the experimental studies consisted of the following commercially available parts: 1) a variable-speed high-pressure gear pump which delivered a constant volume for each speed at pressures from 50 to 100 psig; 2) a heat-exchanger, consisting of four 8-ft lengths of ⅜-inch-ID stainless-steel tubing mounted in 2-inch-ID pipe; 3) a heat-exchanger for cooling, consisting of two 8-ft lengths of ⅜-inch-ID stainless-steel tubing mounted in 2-inch-ID pipe; 4) a pressure relief valve adjustable to different pressures; 5) a by-pass assembly to by-pass the pressure valve; 6) a steam reducing valve to provide steam of any desired pressure to the heat-exchanger; 7) a steam trap to remove condensate from the heat-exchanger; 8) in-line thermometers for measuring the temperature of the heated and of the cooled sirup; and 9) gauges for steam pressures and pumped-sirup pressures. A sketch of the complete apparatus is shown in Fig. 1.

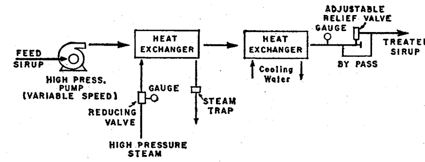

Fig. 1. Flow diagram for continuous high-flavoring of maple sirup.

The volume of the sirup chamber of the heat-exchanger was determined and the pump delivery rates established. In the high-flavoring studies, the sirup was fed to the pump and the system pumped full of sirup at atmospheric pressure. As soon as the sirup emerged from the discharge, the pressure by-pass valve was closed and the pressure relief valve adjusted to maintain 100 psi in the sirup line as shown by the sirup line pressure gauge, or set at a pressure equal to or in excess of the pressure at which the steam is to be fed to the heat-exchanger. Water was then turned on in the cooler (second heat-exchanger) and high-pressure steam was admitted to the heater (first heat-exchanger). Finally, the pressure of the steam was adjusted to provide the temperature desired for the processing of a particular lot of sirup. A thermometer was mounted in the sirup line ahead of the pressure relief valve to indicate the temperature of the processed sirup and to indicate the adjustment of the flow of cooling water (second heat-exchanger) to assure that the temperature of the processed sirup was lower than its atmospheric boiling point before it was discharged from the apparatus.

The extent of flavor and color development in maple sirup is dependent on two interrelated variables: the temperature at which the sirup is heated, and the duration of the heating period. In this continuous process the temperature of the sirup is that of saturated steam for that pressure at which it is supplied to the heat-exchanger. The time of heating is the ratio of the volume of the sirup chamber of the heat-exchanger to the rate at which the sirup is pumped through the exchanger, both volume and rates being expressed in the same units.

To determine the effects of these two variables by the continuous process, a U.S. Grade A sirup was selected for treatment. Based on data obtained with the older batch process, the best high-flavored product would be obtained with this grade. Also, this grade of sirup represents 80% of the total sirup crop.

The sirup was continuously processed under different combinations of conditions, 3 different temperatures (3 saturated steam pressures) with 5 different heating (holding) periods. For each of the 3 heating temperatures, 307, 329, and 338°F, there were 5 different heating times, 4.3, 7.7, 10.6, 15, and 24.3 min. The temperatures were obtained by heating the heat-exchanger with saturated steam at 60, 80, and 100 psi. The different heating times were obtained by changing the speed (rate of discharge) of the gear pump. Samples of the processed sirups representative of the 15 different treatments were taken after the sirup being processed by each set of conditions had reached equilibration. These samples, as well as the original sirup, were analyzed for flavor, color, pH, and invert sugar.

The flavor values indicate number-of-fold increase as measured organoleptically. The untreated commercial sirup was used as a standard. A glass electrode was used to measure the pH of the sirups. The colors were measured by: 1) matching a 1-inch-deep layer of sirup with McAdams color standards; and 2) diluting a weighed amount of the treated sirup with an amount of a colorless sucrose sirup (of the same density) so that the diluted sirup produced a visual match with the original. The number-of-fold increase in color is the ratio of the total weight of the diluted sirup to the origial weight of the maple sirup. The invert sugars were measured by a gas chromatographic procedure based on that described by Wells *et al.* (1964).

The data showing the results of the different treatments are shown in Table 1.

RESULTS AND DISCUSSION

To make possible the use of a continuous process for the heat treatment of maple sirups at temperatures well above their atmospheric boiling point, it was necessary that the process be carried out in a closed system and under sufficient pressure that none of the water in the sirup would be lost as vapor. This technique has been used to pasteurize and process food products in a similar, but not quite parallel, application called high-temperature short-time (HTST). If the heat source is high-pressure steam, as would usually be the case in maple sirup processing, then the sirup should be kept under a pressure equal to, or preferably above, the pressure of the saturated steam being used to heat the sirup.

To keep the time required to heat the sirup to the temperature of the saturated steam as short as possible and to minimize temperature gradients within the sirup, the tubes in the heat-exchanger should be of small diameter.

Table 1 shows that the commercial Grade A sirup reacted in the same general manner when heated at various elevated temperatures in the continuous high-flavoring apparatus. There was a decrease in pH, an increase in maple flavor, a darkening of color, and an increase in invert sugar.

The extent of these changes is related to the amount of heat to which the sirup is exposed, i.e., the temperature and the time of exposure. Fig. 2 shows that at 307°F, the lowest treatment temperature, there was a pronounced increase in maple flavor and only a small increase in caramel flavor even when the hold-up time was extended twofold. It also shows that a hold-up time of 7.7 min at 307° produced the same amount of flavor as was produced in 4.3 min at 324°F. Thus it is possible to achieve the same results by lengthening the time of the lower processing temperature or by raising the temperature and shortening the time of heat treatment. The figure also shows that as the heating temperature was increased a greater amount of caramel was found. The optimum conditions for producing strongest maple-flavored sirup relatively free of caramel for any lot of sirup must be determined experimentally. In the work reported here these conditions were 324°F for 10.6 min. Fig. 2 also shows that as the temperature and time of heating increase, the total flavor in the sirup builds up at an accelerated rate. However, this flavor tends to progressively lose its maple character and becomes acrid and caramel-like. These strongly flavored sirups are no longer valuable for use as pure maple sirups, but do constitute

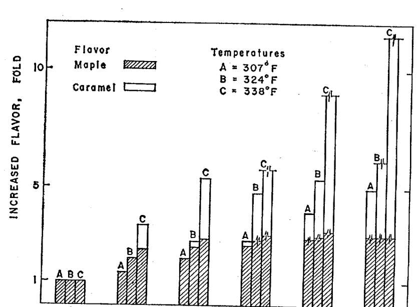

Fig. 2. Flavor developed in maple sirup by heating it at different temperatures for varying lengths of time. Broken lines indicate undetermined limits of each flavor.

Table 1. The effect of heating a U.S. Grade A maple sirup at different temperatures and for different times by the continuous process.

	Temperature																	
	307°F (60 psig, steam)						324°F (80 psig, steam)						338°F (100 psig, steam)					
					Flavor [c]						Flavor [c]						Flavor [c]	
Hold-up time (min)	pH	Color [a]	Color [b]	Invert sugar (%)	Maple	Car.	pH	Color [a]	Color [b]	Invert sugar (%)	Maple	Car.	pH	Color [a]	Color [b]	Invert sugar (%)	Maple	Car.
0	6.75	115	0	0.2	1	0	6.55	115	0	0.2	1	0	6.60	115	0	0.2	1	0
4.3	6.30	140	1.5	1.1	1+	0	5.70	145	1.8	1.3	2	0	5.00	180	3.0	4.9	2+	1
7.7	5.80	155	1.9	1.3	2	0	5.15	175	3.0	3.4	2+	0+	4.50	210	7.4	18	2+	2+
10.6	5.45	175	2.7	2.7	2+	0+	4.80	210	5.0	8.1	2+	2	4.00	more 220	13	50	2+	2+
15.0	5.00	190	4.1	8.6	2+	1	4.30	over 220	10	28	2+	2+	3.45	more 220	42	87	very strong	
24.3	4.58	210	5.4	27	2+	2	3.75	over 220	20	72	2+	2+	3.25	more 220	75	80	very strong	

[a] Color compared to McAdams scale.
[b] Color by dilution method.
[c] Flavor of commercial sirup = 1.

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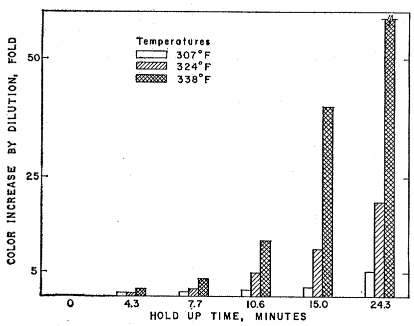

Fig. 3. Color developed in maple sirup by heating it at different temperatures for varying lengths of time.

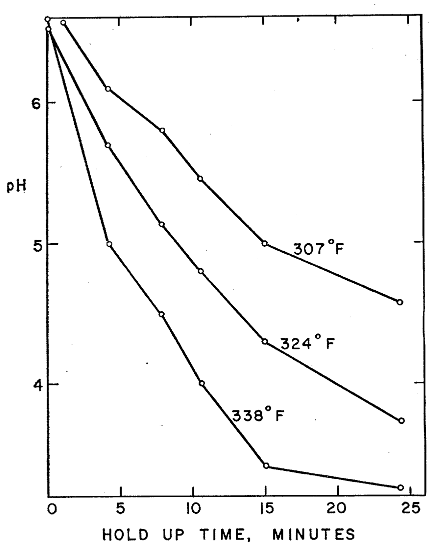

Fig. 4. The ph of a maple sirup heated at different temperatures for varying lengths of time.

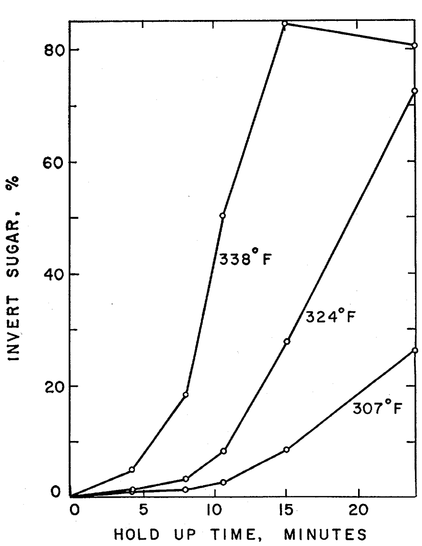

Fig. 5. The invert sugar in maple sirup heated at different temperatures for varying lengths of time.

flavor bases for making blends of cane and maple sirup. Upon dilution with cane sirup, the "caramel"-flavored maple base loses the caramel flavor and the maple again becomes the predominating flavor.

Fig. 3 shows that color was formed in the sirup at an accelerated rate as the temperature of heating was raised. At the lowest processing temperature tested (307°F), increasing the heating time from 4.3 to 24.3 min caused only a 5.6-fold increase in color. When the processing temperature was raised to 338°F, a pronounced color increase occurred. Increasing the hold-up time from 4.3 to 24.3 min, at this higher temperature, caused a 40-fold increase in color, with a sharp break occurring between heating times of 10.6 and 15 min. This is in accord with earlier work (Porter *et al.,* 1952) on the effects of heating sirups. It was also observed that the continuous process, with its much closer control of temperature and time of heating, makes it possible to improve the flavor of the darker grades of sirup without making them too dark to be of commercial value as table sirups.

During the heat treatment, the pH and the invert sugar content also changed. As shown in Fig. 4, the pH of the sirup decreased as the time of heating and amount of heat (temperature) increased. This was reported in earlier work, but additional data are still needed to establish the relationship of pH change to properties of the heated sirup. Fig. 5 shows the changes in the invert sugar content of the commercial sirup as its heating conditions were varied. The increase in invert sugar confirms the results of earlier studies of Hayward and Pederson (1946) and of Porter *et al.* (1952). In addition, each curve in Fig. 5 shows a point where an accelerated rate of invert formation begins for each processing temperature. At higher temperatures, the break point occurred at a lower hold-up time. At 309°F (60 psig steam pressure) the break point was at 10.6 min hold-up time; at 324°F (80 psig pressure) this was at 7.7 min hold-up time; at 338°F (100 lb steam pressure) the break was at or below 4.3 min hold-up time. From the data in Table 1 it can be seen that these break points indicate the conditions at which the "caramel" flavor begins to be predominant. Also, at these break points the decreasing pH of the sirup reaches a value slightly above 5.

To further test the applicability of continuous process, a bland sirup (essentially colorless and flavorless), obtained by vacuum evaporating maple sap, was passed through the apparatus at several different temperatures and hold-up times. The results are shown in Table 2. This sirup yielded products with levels of flavor differing with the treatment used.

These data also show that by this process it is possible to produce in a bland sirup a higher intensity of maple flavor before the caramel flavor becomes significant, than can be produced in a commercial sirup. Likewise, the color of processed bland sirups is less than that produced in processed commercial sirups. These observations are of special value since a recent development in the maple industry has been the conversion of vegetable and fruit processing plants to maple sap concentration plants. Some of these use vacuum evaporation equipment and produce bland maple sirups. These bland sirups must be heat-treated either by the batch or by the new continuous process to develop maple flavor.

The value of this new process is its continuous feature, which makes possible: 1) the close control that can be maintained over the amount of heat and the time of heating; and 2) the ease and rapidity with which these conditions can be changed to produce any type of sirup, ranging from light-colored ones of enhanced flavor to those of dark color and strong flavor.

Table 2. The effect of heating a bland vacuum-concentrated maple sap at different temperatures and for different times by the continuous process.

	Temperature							
	307°F (60 psig, steam)				324°F (80 psig, steam)			
Hold-up time (min)			Flavor				Flavor	
	pH	Color [a]	Maple	Caramel	pH	Color [a]	Maple	Caramel
0	7.80	65	½ [b]	0				
4.3	6.63	120	¾	0				
5.3	6.50	130	¾	0				
7.7	6.10	135	1	0	5.25	145	2 + [b]	½
10.0	5.85	135	1½	0	4.80	160	2 +	½
12.3	5.55	140	2	0	4.45	185	2 ++	1

[a] Color compared to McAdams scale.
[b] Flavor of commercial sirup = 1.